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EARLY SILURIAN AGE OF ROCKS HOSTING LEAD-ZINC MINERALIZATION AT HOWARDS PASS, YUKON TERRITORY AND DISTRICT OF MACKENZIE; LOCAL BIOSTRATIGRAPHY OF ROAD RIVER FORMATION AND EARN GROUP

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Abstract

The Howards Pass stratiform deposit is developed within the lower part (shale-chert unit) of the Road River Formation. Graptolites from surface exposures at Howards Pass document a very late Llandovery age (*spiralis* Zone) for Road River beds well above the deposit. Conodonts and graptolites from drill cores and adit samples establish a latest Early to Middle Llandovery age for the mineralized beds (*cyphus* to *convolutus* graptolite zones; *?kentuckyensis* conodont zone) and Late Llandovery age (*celloni* conodont zone) for closely overlying Road River strata.

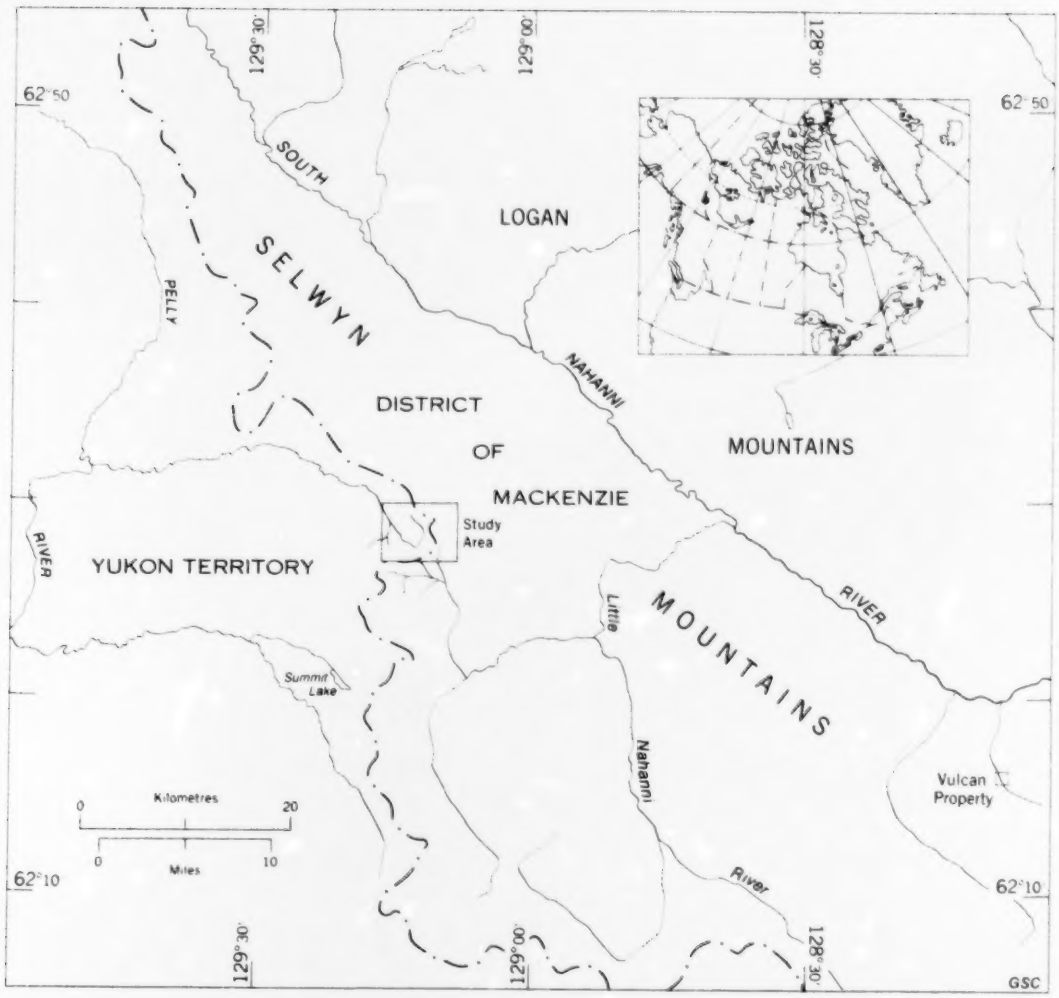
Within the Nahanni map area and adjacent localities, graptolites document ages of early Arenig, Caradoc, Ashgill (*complanatus ornatus* Zone), Early Llandovery (*cyphus* Zone), Middle Llandovery (*convolutus* Zone), Late Llandovery (*spiralis* Zone and *sakmaricus-laqueus* Zone), and Wenlock (*rigidus* Zone) within the lower part (shale-chert unit) of the Road River Formation, but the contact with the underlying carbonate rocks is diachronous. Conodonts from the same shale-chert unit at Howards Pass record the Llandovery *celloni* Zone, questionably the preceding *kentuckyensis* Zone, and a poorly diagnostic fauna of late Wenlock/early Ludlow age. A single collection of Ludlow graptolites from the upper part (orange-weathering mudstone unit) of the Road River most probably represents the *leintwardinensis primus* Zone. Above the Road River Formation, graptolites indicate the Pragian *yukonensis* Zone and probably the *thomasi* Zone from the lower part of the Earn Group. Conodonts from the Earn Group at Howards Pass document a Ludlow horizon (the *ploeckensis* or *siluricus* Zone), the Lochkovian (*delta* Zone and *pesavis* Zone), several levels within the Pragian and Zlichovian (*?sulcatus*, *?kindlei*, *dehiscens* and *gronbergi* Zones), possibly the Eifelian, and late Devonian (Famennian) horizons. The age of the Earn Group ranges from Upper Silurian to mid-Mississippian.

Mazuelloids are present both in the *celloni* Zone of the Road River Formation and in the lower part of the Earn Group. These enigmatic microfossils were first described recently from the *celloni* Zone in northwestern Greenland and also are known from the Upper Silurian of Czechoslovakia.

Résumé

Le gisement stratiforme de Howards Pass est trouvé dans la partie inférieure (unité de schiste argileux et de chert) de la formation de Road River. Les graptolites des affleurements superficiels à Howards Pass indiquent que les couches de Road River bien au-dessus du gisement datent de la toute fin du Llandovérien (zone de *spiralis*) tandis que les conodontes provenant des carottes de forage démontrent que les couches minéralisées (zone de *?kentuckyensis*) datent du Llandovérien moyen ou du début du Llandovérien supérieur et les couches susjacentes de Road River (zone de *celloni*) du Llandovérien supérieur.

Dans la région cartographique de la Nahanni et les régions avoisinantes, les graptolites démontrent que la partie inférieure (unité de schiste argileux et de chert) de la formation de Road River date du début de l'Arénigien, du Caradocien, de l'Ashgillien (zone de *complanatus ornatus*), du Llandovérien inférieur (zone de *cyphus*), du Llandovérien moyen (zone de *convolutus*), du Llandovérien supérieur (zone de *spiralis* et zone de *sakmaricus-laqueus*) et du Wenlockien (zone de *rigidus*); la surface de contact des roches carbonatées sousjacentes est diachrone. Des conodontes provenant de la même unité de schiste argileux et de chert à Howards Pass indiquent la présence de la zone de *celloni* du Llandovérien, peut-être de la zone précédente de *kentuckyensis* et d'une zone indéterminée datant de la fin du Wenlockien au début du Ludlowien. Une seule collection de graptolites ludlowiens de la partie supérieure (unité de mudstone à surface d'altération orangée) de la formation de Road River représenterait la zone de *leitwardinensis primus*. Au-dessus de la formation de Road River, les graptolites identifient la zone de *yukonensis* (Pragien) et probablement la zone de *thomasi* de la partie inférieure du groupe d'Earn. Des conodontes provenant du groupe d'Earn à Howards Pass indiquent la présence d'un horizon ludlowien (zone de *ploeckensis* ou *siluricus*), de l'horizon lochkovien (zone de delta et zone de *pesavis*), de plusieurs niveaux au sein des horizons du Pragien et du Zlichovien (zones de *?sulcatus*, de *?kindlei*, de *dehiscens* et de *gronbergi*), peut-être de l'Eifelien et de la fin du Dévonien (Famennien). Le groupe d'Earn s'étend du Silurien supérieur au Dévonien supérieur.



Textfigure 1. *Locality map.*

Des mazuelloïdes sont présents dans la zone de *celloni* de la formation de Road River et dans la partie inférieure du groupe d'Earn. Ces microfossiles énigmatiques ont été décrits récemment pour la première fois dans la zone de *celloni* dans le nord-ouest du Groenland; ils ont également été identifiés dans le Silurien supérieur en Tchécoslovaquie.

REGIONAL GEOLOGY

The lead-zinc mineralization at Howards Pass (Textfig. 1) has been described as a stratiform deposit (Morganti, 1981) occurring as lenses of extremely fine grained galena and sphalerite within greyish black mudstones, cherts, slates and limestones of the Road River Formation. Ore reserves have been calculated at 110 million tonnes, averaging 5.4 per cent zinc and 2.1 per cent lead, plus some 350 million tonnes of inferred reserves (Placer Development Ltd. quoted by Morin and others, 1982, p. 7-8). Morganti's (1979) detailed description of the deposit used the term Howards Pass Formation (Morganti, 1977) and subdivided it into five members with the mineralization occurring within the second highest, his "Active Zone Member". None of these stratigraphic units has been described formally. Gordey (1980-1981), in regional studies, has not used the term "Howards Pass Formation", but its approximate equivalent is Gordey's shale-chert unit of the Road River Formation, the lower of the two units recognized within the Road River in the Nahanni map area (62° to 63°N, 128° to 130°W, 105I). Although exposures are incomplete and some structural complications are present, the upper unit (orange-weathering mudstone unit) of the Road River Formation provides a very useful stratigraphic marker and allows the formation to be readily discriminated from the overlying Earn Group.

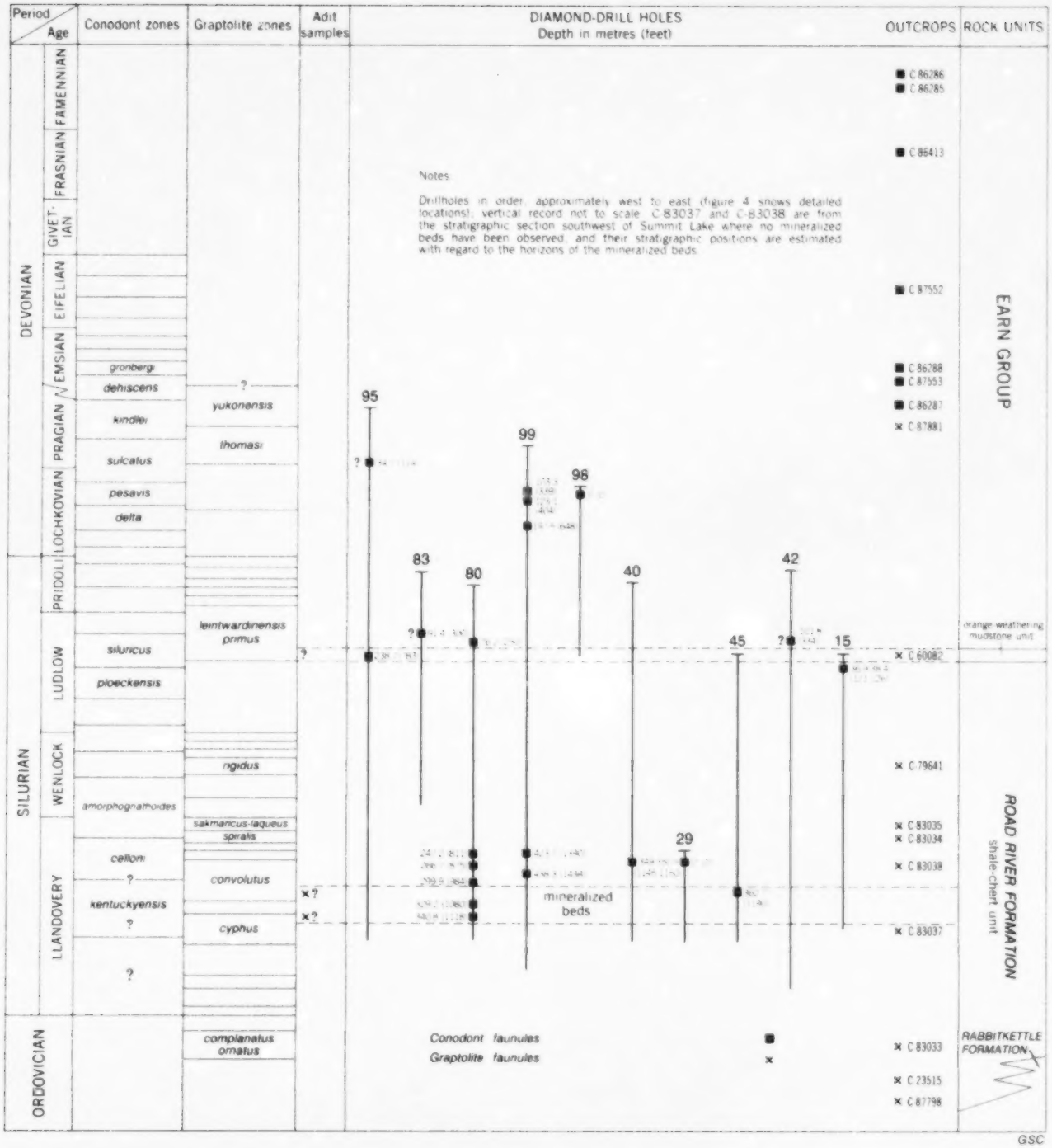
Howards Pass is an informal name for a divide at the Yukon-Mackenzie Boundary at 62°28'N, 129°12'W. There, the depositional environment of the Road River Formation has been interpreted as a sink at the foot of the slope from the front of a Lower Paleozoic carbonate platform toward the outboard Selwyn Basin (Morganti, 1981, p. 71). The Silurian front of the platform runs approximately parallel to, and to the northeast of, the present course of the South Nahanni River (Textfig. 1). At Howards Pass, the Road River Formation overlies limestones of the Rabbitkettle Formation and itself is overlain by siliceous shales of the Earn Group (Gordey and others, 1982). To the northeast and east, toward the Lower Paleozoic carbonate platform, facies changes result in carbonate rocks taking the place of much of the basinal succession. Near the South Nahanni River, Ordovician carbonates at the Vulcan Property are overlain directly by Upper Ordovician Road River Formation (GSC loc. C-83033, see Appendix). Beneath the Road River Formation near Howards Pass, the youngest fossils known from the Rabbitkettle Formation are conodonts that probably are Middle Ordovician (GSC loc. C-87045), but conodonts and trilobites of Early Ordovician (Tremadoc and Arenig) and Late Cambrian age are known regionally from the Rabbitkettle (Tipnis and others, 1978).

GRAPTOLITE BIOSTRATIGRAPHY

Cherts are very common in the Road River Formation in the western and southwestern parts of the Nahanni map area, and graptolites are both rare and commonly poorly preserved. At Howards Pass itself, all known graptolites are sheared, but two distinct faunules (GSC loc. C-83034 and C-83035, see Appendix for details) from outcrops of the shale-chert unit, indicate the *spiralis* Zone and the *sakmaricus-laqueus* Zone (i.e. latest Llandovery, Textfig. 3). Cores from diamond drillholes (DDHs. of later text and in Textfig. 4) at Howards Pass yielded one sample of cleaved graptolites (GSC loc. C-82889) that are no older than Middle Llandovery. Partly mineralized graptolites from an adit into the ore body (GSC loc. C-107951) indicate a Middle or Late Llandovery age for a horizon in the upper part of the mineralized beds. Similarly preserved graptolites from a cross-cut (GSC loc. C-104131) indicate an Early or early Middle Llandovery age for a horizon at least 15 m above the base of the mineralized beds.

About 20 km southwest of Howards Pass and 7 km southwest of Summit Lake, a poorly exposed and structurally complex stratigraphic section presents the best surface stratigraphic control for the Road River Formation in the region. At this locality the maximum thickness of the shale-chert unit is 332 m (ignoring repetition of folded beds) and of the orange-weathering mudstone unit, 108 m. The mineralized beds are absent. Early Llandovery (GSC loc. C-83037, *cyphus* Zone) and Middle Llandovery (GSC loc. C-83038, *convolutus* Zone) graptolites are present at no more than 130 m and 280 m respectively above the Rabbitkettle Formation. The shale-chert unit is about 230 m thick at Howards Pass, and the mineralized beds are about 30 m thick and occur about 120 to 150 m above the base of the shale-chert unit (interpreted from Morganti, 1979, p. 30). The real thickness of the shale-chert unit in the surface section southwest of Summit Lake may be less than at Howards Pass but the *cyphus* Zone horizon may well be the lateral equivalent of some of the lower part of the mineralized beds at Howards Pass. The *convolutus* Zone horizon lies about 52 m below the top of the shale-chert unit near Summit Lake; at Howards Pass the top of the mineralized beds is about 80 m below the top of the shale-chert unit. The top of the mineralized beds would seem to be no younger than *convolutus* Zone. To sum up, the evidence from the occurrences of the graptolite zones at the outcrop section and at Howards Pass indicates that the mineralized beds at Howards Pass probably are latest Early Llandovery to Middle Llandovery in age.

Graptolites have been collected from a number of localities elsewhere in the basinal rocks of the western parts of the Nahanni map area and adjacent Sheldon Lake map area (105J). Identifications of some of the better preserved collections are presented in the Appendix and the graptolite zones that can be documented are indicated on textfigures 2 and 3. It is obvious that the collections dated give a very incomplete representation of the sequence of graptolite zones recognized regionally in the Lower Ordovician to Lower Devonian rocks of northwestern Canada. Unconformities have not been recognized and hiatuses seem unlikely according to the postulated models of sedimentation. The poor exposures of the Road River Formation and the Earn Group, the prevalence of slaty cleavage, and the abundance of chert, may have limited the available evidence so that many zones cannot be identified.



Textfigure 2. *Biostratigraphic data from drillholes and outcrops at and near Howards Pass.*

Notes: Drillholes in order approximately west to east (Textfigure 4 shows detailed locations); vertical record not to scale. Samples from localities C-83037 and C-83038 are from the stratigraphic section southwest of Summit Lake where no mineralized beds have been observed; the stratigraphic positions of these two collections are, therefore, conjectured with regard to the horizons of the mineralized beds.

yukonensis Zone	PRAGIAN	LOWER DEVONIAN	*
thomasi Zone			?
hercynicus Zone	LOCHKOVIAN		
uniformis uniformis Zone			
uniformis angustidens Zone	PRIDOLI	UPPER SILURIAN	
transgrediens Zone			
bouceki Zone			
chelmiensis Zone			
bugensius Zone			
formosus Zone			
leintwardinensis primus Zone	LUDLOW		?
nilssoni Zone			
etheringtoni beds	WENLOCK	LOWER SILURIAN	
testis-lundgreni Zone			
firmus nahanniensis beds			
rigidus Zone			*
cf. *perneri* beds			
centrifugus Zone			
sakmaricus-laqueus Zone	UPPER LLANDOVERY		*
spiralis Zone			*
turriculatus Zone			
sedgwicki Zone			
convolutus Zone	MIDDLE LLANDOVERY		*
gregarius Zone			
cyphus Zone	LOWER LLANDOVERY		*
acinaces Zone			
atavus Zone			
acuminatus Zone			
persculptus Zone ?			
pacificus Zone		ORDOVICIAN	
complanatus ornatus Zone	ASHGILL		*
quadrimucronatus Zone			?
amplexicaulis Zone	CARADOC		?
uncertain interval			
gracilis-bicornis Zone			?
cf. *teretiusculus* Zone	LLANDEILO		
tentaculatus Zone	LLANVIRN		
victoriae Zone	ARENIG		
protobifidus Zone			
fruticosus Zone			
approximatus Zone			*
antiquus Zone	TREMADOC		
aureus Zone			
richardsoni Zone			
tenuis Zone			
uncertain interval			GSC

Asterisks and queries indicate documentation of graptolite zones. The Ordovician zonal terminology is that of Barnes, Norford and Skevington (1981) with modification from Lenz and McCracken (1982). The terminology for the Lower Silurian follows Lenz (1980, 1982) but uses the name *cyphus* Zone for his *gregarius* Zone, and the name *gregarius* Zone for his interval *triangulatus* Zone to *argenteus* Zone. The terminology for the Upper Silurian and Lower Devonian follows Jackson, Lenz and Pedder (1978) modified by the placement of the *formosus* Zone in the basal Pridoli.

Textfigure 3. *Scheme of graptolite zones, northwestern Canada, and documentation in western part of Nahanni map area.*

Textfigure 4. *Location of diamond drillholes, Howards Pass.*

Note: The numbers are those of the individual holes.

CONODONT BIOSTRATIGRAPHY

Conodonts were recovered from 30 of the 51 core samples processed, and from a further 8 samples collected from surface outcrops nearby. Generally, the available core material was not large and many faunules are small and undiagnostic. However, several large faunules and some diagnostic conodonts from small faunules have allowed precise dating of various borehole levels, ranging in age from early Silurian to early Devonian. At the surface, the record extends into the late Devonian. The preservation ranges from poor to good. Many elements are broken, but this does not necessarily render them indeterminate. Conodonts from the ore-zone are relatively small in size, a condition that may have been caused by an inhospitable environment. Also notable is the occurrence of some fused conodont elements, apparently representing partial but natural assemblages: this preservation might be expected only under quiescent bottom conditions or because of rapid burial. Conodonts from the orange-weathering mudstone unit are rare and of undiagnostic character. Those from the early Devonian parts of the Earn Group are relatively common and diverse. All of the conodonts are black in colour, which indicates post-depositional temperatures of between 300°-400°C (Epstein and others, 1977).

Shale-chert unit

Conodonts have been recovered from this unit of the Road River Formation of the Howards Pass region from DDHs. 15, 29, 40, 45, 80, 83, 95 and 99 (see Appendix for details). Small faunules are known from within and immediately above the mineralization ("Active Zone Member" of Morganti, 1977) with the dominant form being *Oulodus* sp. or spp., accompanied by the simple cones *Dapsilodus*, *Walliserodus* and *Panderodus*, with rare *Distomodus*. In slightly higher beds, *Astropentagnathus* is an important addition to the fauna, which also includes enigmatic spherical microfossils termed mazuelloids by Aldridge and Armstrong (1981).

The basal part of the "Active Zone Member" in DDH 80 includes representatives of *Oulodus*?. Two closely allied species may be present or possibly just one (see taxonomic notes). *Oulodus*? cf. *O.*? *kentuckyensis* resembles the species described by McCracken and Barnes (1981, as *O.*? *kentuckyensis*) from Member 6 of the Ellis Bay Formation, Anticosti Island, and regarded as earliest Silurian. The absence of elements indicative of *O.*? *nathani* (the namegiver for the basal Llandovery zone on Anticosti Island) indicates that the base of the "Active Zone Member" may be toward the top of, or above the *nathani* Zone. *O.*? *kentuckyensis* has been recorded from both the *nathani* Zone and the overlying *kentuckyensis* Zone in the Clemville Formation, Gaspé (Nowlan, 1981).

Oulodus? *fluegeli* is a more common constituent of the faunules, especially from within and above the "Active Zone Member". The species appears to be closely related to *O.*? *kentuckyensis* and is known principally from the *celloni* Zone (Late Llandovery). Aldridge (1979) has reconstructed (perhaps partly) the apparatus of this species using *celloni* Zone material from Britain (Aldridge, 1972), the Carnic Alps (Walliser, 1964), and northeastern Greenland. Possible records from younger rocks include those from the Rose Hill Formation of West Virginia (Helfrich, 1980), which is assigned to the *amorphognathoides* Zone, and the discrete element *Trichonodella trichonodelloides*, from as high as the Ludlow *siluricus* Zone in New South Wales (Link and Druce, 1972). The youngest records may represent long-ranging elements that are common to more than one multielement species. Similarly, the oldest records of elements resembling those of *O.*? *fluegeli* may not belong definitely to that multielement species. Records (Klapper and Murphy, 1975, tables 1, 8) of *Neoprioniodus planus* Walliser *sensu formo* from the base of the Pete Hanson Creek Formation in Nevada, in association with *Distomodus kentuckyensis*, could be pre-*celloni* Zone, as could several ramiform elements from Unit 3 of the Ely Springs Dolomite in California (Miller, 1975, 1976a, b).

In summary, early Silurian species of *Oulodus*? constitute a variable complex of elements undergoing a mosaic evolution that may have resulted in many closely allied multielement species differing in detail but having certain elements in common. One such lineage may have included *O.*? *kentuckyensis* and *O.*? *fluegeli*, whose representatives may have coexisted in the *Distomodus kentuckyensis* Zone (approximately mid-Llandovery).

In DDHs. 29, 80 and 99, a siliceous and phosphatic interval above the "Active Zone Member" is characterized by the first appearance of species of *Astropentagnathus*, in addition to the long-ranging *Carniodus* and *Belodella*, and various species that appeared earlier. Two species of *Astropentagnathus* are represented, but they do not occur in the same core and their stratigraphic relationship is unclear. *A. irregularis* Mostler is well known from the *celloni* Zone in Britain (Aldridge, 1972) and the Carnic Alps (Schönlaub, 1971). In the Alps, this fossil appears abruptly above an unconformity and in association with elements referred by Schönlaub to *Falcodus*? n. sp. and "*Rhyncognathodus*" n. sp.; a very similar association occurs within DDH 29. *Pterospathodus celloni* has not been found in association with *A. irregularis* at Howards Pass, whereas the two occur together in the *turriculatus* Zone of the northern Yukon (McCracken and Lenz, 1980), and in the Eids M-66 well 530.3-567.0 m (1740-1860 ft) in southwestern Ellesmere Island (Mayr and others, 1978).

DDH 99 contains a single specimen of *Astropentagnathus* aff. *A. transitans*. No assessment of variability is possible and the form could be new. In terms of morphological trends in *Astropentagnathus*, its equidimensional platform is more advanced than that of *A. irregularis* but it bears fewer platform nodes, which is regarded as a less advanced condition. Its age, like that previously established for similar forms, is regarded tentatively as *celloni* Zone.

Spherical spinose mazuelloids are associated with *Astropentagnathus* in samples DDH29 and DDH99.1340; they occur also in samples DDH80.250, DDH80.811, DDH83.84, DDH83.300 and DDH83.846. These enigmatic microfossils were first described recently from northern Greenland, where they also occur with late Llandovery conodonts. At Howards Pass, mazuelloids occur within the lower part of the Earn Group in beds whose oldest possible age is Ludlow. Mazuelloids also have been reported from the Upper Silurian of Czechoslovakia (Aldridge and Armstrong, 1981, p. 2). The discovery of the Yukon specimens, which differ in morphological detail from the various morphotypes illustrated from Greenland (Aldridge and Armstrong, 1981, Textfig. 1), indicates that the group is widely distributed.

The youngest faunule occurs near the top of the shale-chert unit in DDH 15. As in older associations, a species of *Oulodus*?, close to *O.*? *fluegeli*, is dominant and is associated with various *Walliserodus* morphotypes. The occurrence of a single specimen of *Ozarkodina* cf. *O. douroensis* is significant. This taxon has been reported from 64.3 m below the top of the Cape Storm Formation on Cornwallis Island (Thorsteinsson and Uyeno, 1981), and from near the top of the Read Bay-Allen Bay carbonate unit in the Panarctic Arco et al. Blue Fiord E-46 well (1005.8-1036.3 m) on Ellesmere Island (Uyeno, 1981). At the first location, *O.* cf. *O. duoroensis* occurs 180 m below the first record of *Polygnathoides siluricus*. *O. duoroensis* itself is present 140 m below *P. siluricus* in the same section and is known from lower stratigraphic levels in the Canadian Arctic (Thorsteinsson and Uyeno, 1981, p. 22). This prompted Thorsteinsson and Uyeno to suggest that *O. duoroensis* may range down into beds older than *siluricus* Zone in the Arctic, whereas originally it was reported from the *siluricus* Zone in Nevada (as *O.* n. sp. B of Klapper and Murphy, 1975, p. 13-15). In view of the fact that the Wenlock *rigidus* graptolite Zone has been documented about 9 km to the east of Howards Pass, right at the top of the shale-chert unit (see Appendix), it seems possible that the strata containing *O.* cf. *O. douroensis* in the Yukon are Wenlock in age.

Orange-weathering mudstone unit

This unit of the Road River Formation forms a distinctive stratigraphic marker in southwestern Selwyn Basin and is characterized by a wispy lamination arising from intense bioturbation (Gordey, 1980, p. 353). Conodont faunules generally are sparse and undiagnostic. *Dapsilodus*? and *Walliserodus*? were recovered from DDH 45 and DDH 80 respectively, and *Ozarkodina excavata excavata* from DDH 95. The species has a reputed range within the late Llandovery (Aldridge, 1975), through the *amorphognathoides* Zone (Jeppsson, 1979) and, in the Carnic Alps, from within the *patula* Zone of the Wenlock through the early Devonian (Walliser, 1964). The faunules can be dated only as Silurian, but constraints imposed by the ages of conodont faunules short distances below and above the unit indicate that it is largely or wholely Ludlow, as attested by the single collection of graptolites from the unit.

Lower Earn Group

The siliceous shale unit of Gordey (1981) recently has been referred to the lower part of the Earn Group (Gordey and others, 1982). Conodonts demonstrate that this unit spans a considerable interval of time, from Ludlow to Famennian.

At Howards Pass, the stratigraphically lowest conodonts from the Earn Group occur in DDH 42 where a single element, referred to *Ozarkodina* cf. *O. excavata excavata*, was recovered at a depth of 334 feet (102 m), immediately above the orange-weathering mudstone unit. The same species may occur also in DDH 83 at 300 feet (91.5 m). As discussed earlier, *O. excavata excavata* is present in the upper unit (orange-weathering mudstone) of the Road River Formation and there may be stratigraphic continuity between the two units.

Within DDH 80, at 250 feet (76 m), a small conodont faunule, located about 8 m above the Road River, includes a single specimen of *Ancoradella ploeckensis*, a species of Ludlow age. The species has been described from the Carnic Alps (Walliser, 1964), the Yass Basin in Australia (Link and Druce, 1972), Nevada (Klapper and Murphy, 1975) and from the Canadian Arctic (Uyeno, 1981). At Cellon, in Nevada (Klapper and Murphy, 1975, p. 12) and in the Canadian Arctic (Thorsteinsson and Uyeno, 1981, Fig. 16), the nominate species of the *ploeckensis* and *siluricus* zones overlap stratigraphically. The Yukon faunule could indicate either zone.

The oldest Devonian faunule is identified at 648 feet (197.5 m) within DDH 99 and includes a single specimen of *Ozarkodina transitans*, α morphotype of Lane and Ormiston. This is a cosmopolitan species that ranges within the Lochkovian *delta* and early *pesavis* Zones (Klapper and Johnson, 1980; Klapper and Murphy, 1980). Separation of the species into four morphotypes by Lane and Ormiston (1979) has yet to demonstrate stratigraphic utility, although Chlupáč and others (1980) illustrated forms from Czechoslovakia corresponding to the α morphotype that occurred at higher levels (but still within the *delta* Zone) than more nodose varieties.

At stratigraphically higher levels, at 339 feet (103.3 m) and 404 feet (123 m) within DDH 99, and at the collar of DDH 98, faunules dominated by representatives of the *Pandorinellina steinhornensis* group occur. These are problematic forms with uncertain range and origin (Cooper, 1980, p. 225; Murphy and others, 1981, p. 762). The specimens are of a kind commonly associated with Emsian polygnathids in the Yukon, but here are regarded as older because associated icriodids correspond to a broad concept of *Icriodus steinachensis*. About half of these icriodids correspond to the eta morphotype of Klapper and Johnson (1980); the others, in part coexisting, may belong to a new morphotype. The range of the eta morphotype of *I. steinachensis* is *pesavis* Zone (Klapper and Johnson 1980, tables 3, 4). Data in Murphy and others (1981, p. 755, 762) indicate that the eta morphotype may appear below the *pesavis* Zone in Nevada. Faunal associates at DDH 98 include one element of *Oulodus? walliseri*, a species that ranges up to the *pesavis* Zone (Pickett, 1980), and several elements resembling *Ozarkodina selfi*. The latter exhibit a flattening of the posterior carina, regarded as an initial development leading to *Eognathodus sulcatus juliae*, which appears in the *sulcatus* Zone. On balance, the age of these *steinachensis-steinhornensis* associations is regarded as *pesavis* Zone.

A slightly younger (Pragian) age may be represented by a specimen referred to as *Ozarkodina* cf. *O. eberleini* in sample DDH95.114. The species is known from southeastern Alaska within the *sulcatus* and *kindlei* Zones, but is very similar to an older (Lochkovian) species, *O. remscheidensis repetitor*.

Outcrops of the siliceous shale unit near Howards Pass can be dated precisely on the basis of the species *Polygnathus pireneae*, *P.* aff. *P. dehiscens* and *P. gronbergi*, each of which occurs in distinct faunules from isolated outcrops (see Appendix). These indicate respectively the *kindlei* (or *dehiscens*), *dehiscens* (or *gronbergi*), and *gronbergi* Zones of late Pragian and Zlichovian age (see Klapper and Johnson, 1980, tables 4, 5). The faunule containing numerous specimens of *P.* aff. *P. dehiscens* also includes *Icriodus taimyricus*, which supports a *dehiscens* Zone age. Another outcrop yielded a single fragment resembling *Tortuodus kockelianus*, indicative of middle to late Eifelian. Three further outcrops yielded palmatolepids including *Palmatolepis* cf. *P. triangularis* and *P. glabra*. The age of the oldest of these faunules may be latest Frasnian, that of the youngest is early to middle Famennian (Klapper and Ziegler, 1979).

BIOSTRATIGRAPHIC SUMMARY

Textfigure 2 portrays all the biostratigraphic information known from Howards Pass (both subsurface and outcrop) and relevant outcrops nearby. The orange-weathering mudstone marker unit of the Road River Formation is Upper Silurian (Ludlow). Above it, several Lower Devonian (Lochkovian, Pragian, Emsian) and younger horizons are documented from the Earn Group, and conodont faunules indicate that the basal Earn is Upper Silurian (Ludlow). Below the marker unit, Ordovician horizons are known regionally from the shale-chert unit of the Road River Formation, but, at the X-Y Deposit at Howards Pass, all the available paleontological data indicate a Lower Silurian (Llandovery) age, except for an upper Wenlock or lower Ludlow conodont faunule right at the top. Both graptolites and conodonts indicate Upper Llandovery horizons above the mineralized beds at Howards Pass. Conodonts from the mineralized beds indicate the *kentuckyensis* Zone (upper Lower or Middle Llandovery); graptolites indicate probable *cyphus* and *convolutus* Zones (high Lower and Middle Llandovery). Lithological correlation with well dated horizons within an unmineralized stratigraphic section 20 km to the southwest supports the suggestion that the mineralized beds at Howards Pass lie within the *cyphus* Zone to *convolutus* Zone (uppermost Lower and Middle Llandovery) interval.

TAXONOMIC NOTES

Some of the more biostratigraphically significant graptolites and conodonts are illustrated and described. The graptolites are all from outcrops at Howards Pass and elsewhere in the western Nahanni map area. The conodonts are from both boreholes and outcrops. Relationships between conodont data and graptolite data are inferred from relative stratigraphic positions as the authors have no collections

yielding both graptolites and conodonts. Illustrated specimens have been deposited in the type collection of the Geological Survey of Canada, and bear numbers of that collection.

GRAPTOLITES
(B.S. Norford)

Genus *Atavograptus* Rickards, 1974

Atavograptus aff. *A. gracilis* Hutt, 1975

Plate 4, figure 15

aff. 1970 *Monograptus* sp. 2 of Hutt and Rickards, p. 72, 76; figs. 3e, 3f.
aff. 1975 *Atavograptus gracilis* Hutt, p. 63; Textfig. 14-4; Pl. 14, fig. 4.

Material: A single incomplete specimen, GSC loc. C-83037, *cyphus* Zone.

Remarks: The specimen (20 mm long) is very narrow (width 0.3 mm) with a moderately dorsally convex rhabdosome; the sicular region is obscure. Straight, simple thecae number about 7 in 10 mm, with very small apertures. *A. gracilis* was described from the *atavus* Zone, the present form differs by its convex shape and perhaps by being more slender. Hutt's illustrations show a rhabdosome width of 0.4 to 0.6 mm for the holotype and 0.3 to 0.4 mm for other material. However, her text mentions on a maximum width of 0.8 mm, proximal widths of less than 0.2 mm, with most fragments 0.5 to 0.6 mm wide.

Genus *Cyrtograptus* Carruthers, 1867

Cyrtograptus cf. *C. laqueus* Jackson and Etherington, 1969

Plate 4, figures 1 and 3

cf. 1969 *Cyrtograptus laqueus* Jackson and Etherington, p. 1119-1121; textfigs. 4A, 4B, Pl. 130; figs. 1-3.

Material: Parts of at least 16 poorly preserved rhabdosomes; GSC loc. C-83035; *sakmaricus-laqueus* Zone.

Remarks: The specimens are distorted and associated so closely as to obscure each other, but 2 rhabdosomes show 3 cladia separated by 3 or 4 thecae. Such spacing, the small number of cladia, the mode of coiling with the rhabdosome's proximal part lying outside the coil, and the common twisting through 180° of the main stipe beyond the last cladium, all indicate *C. laqueus*, but the preservation is inadequate for precise identification.

Genus *Monograptus* Geinitz, 1852

Monograptus gregarius arcuatus (Obut and Sobolevskaya, 1968)

Plate 4, figures 16-18

1968 *Coronograptus gregarius arcuatus* Obut and Sobolevskaya, p. 94-95; Pl. 21, figs. 2-11; Pl. 22, figs. 1, 2.
1982 *Coronograptus gregarius arcuatus* Obut and Soblevskaya; Lenz, p. 53; figs. 5C, 5D, 5R, 20F-20H, 20J.

Material: Numerous small specimens; GSC loc. C-83037; *cyphus* Zone.

Remarks: Narrow rhabdosome with long, almost straight sicular region (3-4 mm long), followed by moderate dorsal curvature that lessens distally; maximum observed length 17 mm. Sicula extends at least to aperture of second theca, sicula's aperture with short, slender ventral spine that parallels axis of sicula and probably is part of virgella. Rhabdosome width reaches 0.4 mm at length of 15 mm; thecae number 5 in 5 mm, somewhat fewer proximally, small slightly flared apertures. Obut's and Sobolevskaya's illustrations show more widely spaced thecae (3.5 to 4 in 5 mm) and the stipe width is given as 0.5 to 0.7 mm, somewhat larger than the present material. Lenz's material has rhabdosomes of intermediate width (0.4-0.55 mm) and spacing of thecae (4 to 5 in 5 mm).

Monograptus buddingtoni Churkin and Carter, 1970

Plate 4, figure 9

1970 *Monograptus buddingtoni* Churkin and Carter, p. 36-37; textfigs. 15D, 15E; Pl. 4, figs. 7, 8.

Material: Several rhabdosomes; GSC loc. C-83038; *convolutus* Zone.

Remarks: Rhabdosome small (illustrated specimen about 15 mm long), distally straight with evenly dorsally curved proximal part; width about 0.4 mm at first theca, increasing gradually to about 0.7 mm at twentieth theca. Sicula poorly preserved, reaching to near aperture of first theca; thecae simple, overlapping by about one third of their length distally; apertures virtually orthogonal to stipe direction; thecal spacing about 7 in 5 mm.

Monograptus cf. *M. clingani* (Carruthers, 1867)

Plate 4, figure 10

1867 *Graptolithus Clingani* Carruthers, p. 369; Pl. 2, fig. 8.
1975 *Monograptus clingani* (Carruthers); Hutt, p. 82; Textfig. 19-9; Pl. 23, figs. 5-7 (see for synonymy).
1975 *Monograptus clingani* (Carruthers); Bjerreskov, p. 67-68; fig. 20E.
1982 *Monograptus clingani* (Carruthers); Lenz, p. 65, 67; figs. 5U, 5V, 21E, 21K.

Material: Two incomplete rhabdosomes, several fragments; GSC loc. C-83038; *convolutus* Zone.

Remarks: Proximal parts missing from both rhabdosomes, which are gently dorsally curved, width increasing gradually to about 1.5 mm at length of 20 mm, of which almost half is the pronouncedly hooked portion of the thecae; apertures face proximally; thecal spacing 4.5 to 5 in 5 mm.

Monograptus cyphus Lapworth, 1876

Plate 4, figure 19

1876 *Monograptus cyphus* Lapworth, p. 352; Pl. 12, figs. 3a, 3c (not 3b, 3d).
1975 *Coronograptus cyphus cyphus* (Lapworth); Hutt, p. 67-68; Pl. 12, figs. 6, 11, Pl. 14, figs. 6, 7 (see for synonymy).
1975 *Monograptus cyphus* Lapworth?; Bjerreskov, p. 45; fig. 14D.

Material: A single specimen; GSC loc. C-83037; *cyphus* Zone.

Remarks: Rhabdosome at least 40 mm long, sicula straight, rhabdosome about 0.3 mm wide at first theca, even dorsal curvature for next 20 mm, almost straight distally where 1 mm wide. Sicula obscure; thecae simple, strongly overlapping, 5 to 5.5 in 5 mm. Lenz (1982, p. 50, 52; Fig. 4F) reported *Coronograptus* cf. *C. cyphus* from the Richardson Mountains, Yukon, but his material appears to be too poorly preserved to allow more precise identification.

Monograptus triangulatus (Harkness) variety cf. *M.? triangulatus? orbitus* (Churkin and Carter, 1970)

Plate 4, figure 7

cf. 1970 *Rastrites orbitus* Churkin and Carter, p. 45; figs. 19A, 19B; Pl. 4, figs. 18, 19.

Material: One rhabdosome, several fragments; GSC loc. C-83038; *convolutus* Zone.

Remarks: Most complete rhabdosome about 20 mm long, gently and evenly dorsally curved, but stipe twisted through 180° at about sixth theca; attaining width of about 1.2 mm distally. Sicular region poorly preserved, as are first few thecae; first theca apparently triangular; next 7 apparently narrow, isolate and orthogonal; next 10 thecae isolated, at high angle to rhabdosome, becoming progressively more triangular, with small recurved hooked terminations; more distal thecae triangular; thecal spacing 5 in 5 mm.

The taxon is similar to *Monograptus simulans* Pederson, as described by Bjerreskov (1975, p. 79; Fig. 23E; Pl. 11G) but both the proximal rastritiform and the distal triangular thecae are larger (1.8 to 1.9 mm) in *simulans*. In dimension, the present material is very similar to *Rastrites orbitus* whose holotype shows only the proximal 10 thecae (Churkin and Carter, 1970; Fig. 19A; Pl. 4, fig. 18) of which the first seven are rastritiform but the next few may be triangular. A paratype (*ibid.*, Pl. 4, fig. 19) shows numerous more distal thecae that appear to be triangular. If so, then *orbitus* is considered to be more appropriately a variety of *Monograptus triangulatus* than a species of *Rastrites*.

Monograptus aff. *M. sidjachenkoi* (Obut and Sobolevskaya, 1965)

Plate 4, figure 8

aff. 1965 *Pernerograptus sidiachenkoi* (*sic*) Obut and Sobolevskaya, p. 61; Pl. 9, figs. 2-4.
aff. 1967 *Pernerograptus sidjachenkoi* Obut and Sobolevskaya; Obut and Sobolevskaya, p. 111-112; Pl. 15, figs. 2-7.
aff. 1982 *Monograptus sidjachenkoi* (Obut and Sobolevskaya); Lenz, p. 109-110; figs. 8N, 8P, 8R, 27B, 27E, 27F.

Material: One rhabdosome, several fragments; GSC loc. C-83038; *convolutus* Zone.

Remarks: Proximal part of rhabdosome with moderate dorsal curvature that decreases distally, so that rhabdosome is almost straight at length 15 mm, width about 0.5 mm at second theca, increasing rapidly to 1.0 mm at sixth theca and this width maintained distally. Sicula 1.5 mm long, reaching beyond first theca; aperture with fine dorsal spine. Thecae biform; proximal thecae with pronounced lobation that bears a fine dorsal spine; distal thecae with small aperture hooded by a fine lobe that similarly bears a pronounced spine, small excavation at base of next theca just above lobe; thecal spacing 5 in 5 mm.

The taxon resembles *sidjachenko* as described by Lenz but his illustrations and those of Obut and Sobolevskaya show rhabdosomes that are hooked proximally or even coiled. The original spelling of the species name was *sidiachenkoi* in honour of А.И. Сидяченко but was changed to *sidjachenkoi* by the same authors two years later, without comment. This change can be considered as a justified emendation (Article 33 of International Code of Zoological Nomenclature, Stoll and others, 1961) that rectified an incorrect transliteration.

Monograptus ex gr. *M. spiralis* (Geinitz, 1842)

Plate 4, figure 4

ex gr. 1842 *Graptolithus spiralis* Geinitz, p. 700; Pl. 10, figs. 26-27.
ex gr. 1975 *Monograptus spiralis* (Geinitz); Hutt, p. 106-107; Textfig. 21-3.
ex gr. 1975 *Monograptus spiralis* (Geinitz); Bjerreskov, p. 72-73; figs. 20F-20H; Pl. 11c (see for synonymy)
ex gr. 1982 *Monograptus spiralis* (Geinitz); Lenz, p. 111-112; figs. 9P, 32A-32C, 32F.

Material: Parts of 4 rhabdosomes; GSC loc. C-83034; *spiralis* Zone.

Remarks: Preservation is poor but the best specimen shows 4 whorls in the open spire, typical of the group of species, and reaching a diameter of more than 30 mm. Thecae about 4 in 5 mm distally, where rhabdosome width approaches 3 mm.

Genus *Petalograptus* Suess, 1851

Petalograptus cf. *P. palmeus* (Barrande, 1850)

Plate 4, figure 6

cf. 1850 *Graptolithus palmeus* Barrande, p. 61; Pl. 3, figs. 3-4.
cf. 1970 *Petalograptus palmeus* (Barrande); Churkin and Carter, p. 32; Textfig. 13G; Pl. 3, fig. 6.
cf. 1975 *Petalograptus palmeus* (Barrande); Bjerreskov, p. 33-34; Pl. 4J (see for synonymy).

Material: Two rhabdosomes; GSC loc. C-83038; *convolutus* Zone.

Remarks: Larger rhabdosome 17 mm long, width 2 mm at third theca, maximum width almost 3 mm at about 6 mm from proximal end, tapering gradually distally; 5 to 5.5 thecae in 5 mm. The taxon has the tapered look of *P. palmeus* but is slightly wider and has less closely spaced thecae.

Petalograptus sp.

Plate 4, figure 13

Material: Three small rhabdosomes; GSC loc. C-83038; *convolutus* Zone.

Remarks: All the specimens are small, maximum length 6 mm, maximum width 3.5 mm. Sicula large with prominent virgula; 5 thecae present on both sides. In size, the specimens resemble *P. minor* Elles but they could represent young stages of another species.

Genus *Rastrites* Barrande, 1850

Rastrites cf. *R. longispinus* Perner, 1897

Plate 4, figure 11

cf. 1897 *Rastrites peregrinus* var. *longispinus* Perner, p. 9; Textfig. 7; Pl. 13, figs. 32-35.
cf. 1975 *Rastrites longispinus* Perner; Hutt, p. 113-114; Textfig. 26-7; Pl. 25, figs. 2, 4, 5; Pl. 26, figs. 3, ?6.
cf. 1975 *Rastrites longispinus* Perner; Bjerreskov, p. 82; Pl. 12C (see for synonymy).

Material: A few fragments; GSC loc. C-83038; *convolutus* Zone.

Remarks: Rhabdosome dorsally curved with isolated, narrow, (0.2 mm or less) orthogonal thecae that are at least 2.5 mm, long, spaced about 5 in 5 mm. The material is inadequate for positive identification with *longispinus* and there is the possibility that the fragments are mesial or proximal fragments of *R. pheloides* that is present in the same collection. Hutt (1975; Pl. 26, fig. 1) illustrated a rhabdosome fragment with the distinctive apertural features of *pheloides* and this fragment either is continuous with or juxtaposed close to a rhabdosome fragment with long slender thecae very suggestive of *longispinus*. From her illustration, the continuity of the two fragments is equivocal but her text describes the fragments as a single specimen. Lenz (1982; figs. 11G, 11J, 11M, 37A, 37B) illustrates large fragments of *pheloides* that show no such *longispinus*-style portion.

Rastrites pheloides, Törnquist, 1887

Plate 4, figure 12

1887 *Rastrites pheloides* Törnquist, p. 490; Textfig. 1.
1975 *Rastrites pheloides* Törnquist; Hutt, p. 115-116; Textfig. 26-9; Pl. 26, fig. 1 (see for synonymy)
1982 *Rastrites pheloides* Törnquist; Lenz, p. 133; figs. 11G, 11J, 11M, 37A, 37B.

Material: Several small fragments; GSC loc. C-83038; *convolutus* Zone.

Remarks: Rhabdosome dorsally curved with isolate, orthogonal thecae about 2 mm long, 0.4 mm wide and spaced about 6 in 5 mm. Apertures flared with pair of thin spines, 1.5 mm long. Hutt commented that both the type Scandinavian and the British material are from the upper part of the *convolutus* Zone; Lenz reports it from throughout the *convolutus* Zone in the upper canyon of the Peel River, and also from subjacent beds that may belong to the underlying zone.

Genus *Retiolites* Barrande, 1850

Retiolites sp.

Plate 4, figure 5

Material: Two poorly preserved rhabdosomes; GSC loc. C-83034; *spiralis* Zone.

Remarks: Rhabdosome more than 50 mm long and 3.5 mm wide distally. One rhabdosome shows about 3 thecae in 5 mm, the other about 7, but the latter specimen may be distorted. The material is suggestive of *Retiolites geinitzianus geinitzianus* (Barrande).

CONODONTS
(M.J. Orchard)

Genus *Ancoradella* Walliser, 1964

Ancoradella ploeckensis Walliser, 1964

Plate 2, figure 1

1964 *Ancoradella ploeckensis* Walliser, p. 28-29; Pl. 7, fig. 10; Pl. 16, figs. 16-21.
1981 *Ancoradella ploeckensis* Walliser; Uyeno, p. 46; Pl. 8, figs. 17, 18, 19?, 20, 21, (see for synonymy)

Material: A single relatively well preserved platform element was recovered. Associated ramiforms are mostly fragmentary; GSC loc. C-87094.

Remarks: A single M element resembles that illustrated by Uyeno (1981) and questionably included by him in this apparatus.

Genus *Astropentagnathus* Mostler, 1967

Astropentagnathus irregularis Mostler, 1967

Plate 2, figures 2, 3, 6

1967 *Astropentagnathus irregularis* Mostler, p. 298-300; Pl. 1, figs. 1-11.

1975 *Astropentagnathus irregularis* Mostler; Klapper and Murphy, p. 24-25; Pl. 1, figs. 1, 15-18 (see for synonymy).

Material: GSC loc. C-86423.

Remarks: Both Pa and Pb elements have been described by Schönlaub (1971) who suggested that ramiform elements like that identified as "*Rhyncognathodus*" n. sp. were a multielement associate. Klapper and Murphy (1975) also found this element at Birch Creek in Nevada and its occurrence at Howards Pass further supports the relationship.

Astropentagnathus aff. *A. transitans* (Schönlaub, 1971)

Plate 2, figure 5

?1968 *Neospathognathodus ceratoides* Nicoll and Rexroad, p. 46; Pl. 1, figs. 1-4.
aff. 1971 *Hadrognathus transitans* Schönlaub, p. 43; Pl. 1, figs. 12-16.

Material: GSC loc. C-87548.

Remarks: This element resembles the form-species *transitans* but differs in bearing only single nodes on each of three subequal lateral lobes, in contrast to the two to five nodes on each of the unequal lobes of *transitans*.

Elements corresponding to *N. ceratoides* s.f. have not been recovered and, thus, that specific name has not been used. Schönlaub brought together the platform elements as a multielement species of *Hadrognathus*. The present species is referred to *Astropentagnathus* because of its general similarity, in upper and lower views, to *A. irregularis* s.f., and because the type species of *Hadrognathus*, *H. staurognathoides* has been reconstructed as part of a *Distomodus* apparatus.

Genus *Distomodus* Branson and Branson, 1947; emend. Cooper, 1975

Distomodus? sp.

Plate 1, figure 4; Plate 2, figure 7

Material: GSC loc. C-87548.

Remarks: Exognathiform (Sa) and possible 'arrectiform' (M) elements of early Silurian *Distomodus*, or a closely allied multielement taxon, have been found, but the diagnostic platform elements are absent. Very similar ramiform elements also occur within the Upper Ordovician, as early as the low Cautleyan in Britain (Orchard, 1980), as part of the multielement *Birksfeldia*.

Genus *Icriodus* Branson and Mehl, 1938

Icriodus steinachensis Al-Rawi, 1977, *sensu lato*

Plate 3, figures 4, 5, ?11, 13, 17, 18 and ?24

1977 *Icriodus steinachensis* Al-Rawi, p. 55-56; Pl. 5, figs. 42, 43.
1979 *Icriodus steinachensis* Al-Rawi; Lane and Ormiston, p. 52; Pl. 4, figs. 28, 29 (see for synonymy).
1980 *Icriodus steinachensis* Al-Rawi; Klapper and Johnson, Pl. 2, figs. 19-22, 25-27.
1981 *Icriodus steinachensis* Al-Rawi; Johnson and Klapper, Pl. 1, figs. 13-16, 18, 19.

Material: GSC locs. C-87548, C-86424.

Remarks: Two varieties embraced by a broad concept of this species occur at Howards Pass. One (Pl. 3, figs. 17, 18) corresponds to the eta morphotype of Klapper and Johnson (1980) in having maximum platform width at mid-length. The other (Pl. 3, figs. 4, 5), which coexists with the first in DDH 98 and DDH 99.404, has more discrete denticles, relatively fewer of them on the platform, a longer blade, and a maximum width at the posterior end of the platform. In the last respect, the form is close to the beta morphotype of Klapper and Johnson (1980), but it differs in the other respects discussed earlier.

Genus *Oulodus* Branson and Mehl, 1933

Oulodus? *fluegeli* (Walliser, 1964)

Plate 1, figures 2, 9, 10, 12-14, 16-18, 20 and 21;

Plate 2, figures 8, 9, 12, 15, 16, 23 and 24

1964 *Lonchodina fluegeli* Walliser, p. 44; Pl. 6, fig. 4; Pl. 32, figs. 22-24.
1979 *Oulodus*? *fluegeli* (Walliser); Aldridge, p. 14-15; Pl. 2, figs. 6-10, ?11 (see for synonymy).
?1979 *Oulodus* sp. A; Aldridge, p. 13-14; Pl. 2, fig. 14.

Material: GSC locs. C-86324, C-86423, C-87094.

Remarks: This species has been reconstructed by Aldridge based on material from the Carnic Alps, Britain and Greenland. This, or a closely allied species, also occurs in New South Wales (Link and Druce, 1972; Pickett, 1978, Pl. 1, fig. 33), in California (e.g. Miller, 1976b; Pl. 1, figs. 22-25, 31), and in West Virginia (Helfrich, 1980; Pl. 1, figs. 7, 12, ?8). The present material does not include a ligonodiniform (Sc) element like that included in the species by Aldridge (1979), who expressed doubt about the affinity of that particular element. The Greenland fauna does include a ligonodiniform element (referred to *Oulodus* sp. A), that is also a constituent of the Yukon material. This element is comparable to the name-bearing element of *Oulodus*? *kentuckyensis* (Branson and Branson), a possible progenitor of *O.*? *fluegeli*. The Yukon species may, therefore, differ from *Oulodus*? *fluegeli* in the character of its Sc element, or, alternatively, this ligonodiniform element may be common to both multielement species of *Oulodus*?. *Ozarkodina plana* (Walliser, 1964) sensu Sweet and Schönlaub (1975) also includes elements of a type included in *Oulodus*? *fluegeli* by Aldridge (1979), who has discussed this, as well as the generic assignment of the species. Middle to late Silurian records of certain ramiform elements questionably included herein may similarly refer to records of similar elements of different species.

Oulodus? cf. *O.*? *kentuckyensis* (Branson and Branson, 1947)

Plate 1, figures, 1, ?3, ?6, ?7, ?8 and ?11

cf. 1947 *Ligonodina kentuckyensis* Branson and Branson, p. 555; Pl. 82, figs. 28, 35.
cf. 1981 *Oulodus*? *kentuckyensis* (Branson and Branson); McCracken and Barnes, p. 80-81; Pl. 6, figs. 1-20 (see for synonymy).

Material: GSC locs. C-86324, C-87094, C-87548.

Remarks: The elements of this species have been described by McCracken and Barnes. No elements comparable with their zygognathiform and euprioniodiniform have been found at Howards Pass, but elements similar to their oulodiform and trichonodelliform elements occur in several samples, including the large fauna (H40.1145-50) in which some forms referred to *Oulodus*? *fluegeli* may be common to both multielement species.

The trichonodelliform (Sa) elements questionably included here have upturned postero-aboral margins that are rounded apically; this contrasts with the acute angle in the homologous element of *O.*? *fluegeli*. These Sa elements have shorter processes than in *O.*? *kentuckyensis*, although this might result from their relatively small size. However, it is uncertain whether these specimens are early growth stages or simply representatives of a small species.

Oulodus? *walliseri* (Ziegler, 1960)

Plate 3, figure 25

1960 *Lonchodina walliseri* Ziegler, p. 188; Pl. 14, figs. 6, 7.
1980 *Delotaxis walliseri* (Ziegler); Pickett, p. 79-81; Pl. ??, fig. 10.

Material: GSC loc. C-86424.

Remarks: A single distinctive walliseriform (Sb) element has been found. The multielement species has recently been described from New South Wales by Pickett who has presented a long synonymy.

Genus *Ozarkodina* Branson and Mehl, 1933

Ozarkodina cf. *O. duoroensis* Uyeno, 1981

Plate 2, figures 13 and 14

1981 *Ozarkodina* cf. *O. duoroensis* Uyeno; Uyeno p. 41; Pl. 4, figs. 13, 14 (see for synonymy).

Material: GSC loc. C-87550.

Remarks: This species, represented by a single specimen, has a single set of accessory denticles unlike the species *duoroensis*, which has several. Identical specimens have been illustrated by Uyeno (1981).

Ozarkodina cf. *O. eberleini* Savage, 1977

Plate 3, figure 14

cf. 1977 *Ozarkodina eberleini* Savage, p. 281; Pl. 1, figs. 24-32.

Material: GSC loc. C-102863.

Remarks: A few poorly preserved spathognathodiform elements are characterized by prominent denticles at both ends and at mid-length, above the basal cavity. These features are shared by *O. remscheidensis repetitor* (Carls and Gandl) and in the absence of better material, it is difficult to be sure which species is represented at Howards Pass.

Ozarkodina aff. *O. selfi* Lane and Ormiston, 1979

Plate 3, figure 16

aff. 1979 *Ozarkodina selfi* Lane and Ormiston, p. 57; Pl. 3, figs. 9, 18-20.

Material: GSC loc. C-86424.

Remarks: A few specimens occur that compare very closely with *O. selfi*, the precursor to species of *Eognathodus* according to Lane and Ormiston (1979, fig. 6). They differ in having a basal cavity that is more constricted at the posterior end, and in bearing several denticles above the centre of the basal cavity that are flattened and relatively broad. This may be an initial development within a lineage leading to *E. sulcatus juliae*, which has indented medial denticles.

Ozarkodina transitans (Bischoff and Sannemann, 1958)

1958 *Spathognathodus transitans* Bischoff and Sannemann, Pl. 13, figs. 4, 5, 12, 14.

α morphotype of Lane and Ormiston, 1979

Plate 3, figure 2

1979 *Ozarkodina transitans* (Bischoff and Sannemann); Lane and Ormiston, p. 58; Pl. 3, fig. 21.
1980 *Ozarkodina transitans* (Bischoff and Sannemann); Chlupáč and others, Pl. 5, figs. 8, 10.

Material: GSC loc. C-87548.

Remarks: This morphotype is characterized by two small lateral lobes bearing single nodes. The Yukon specimen, which is broken anteriorly, displays nodose lobes that are longitudinally compressed. Consequently, the specimen resembles *Pandorinellina steinhornensis telleri* Schulze, a species characterized by ridges rather than discrete nodes on the lateral lobes. Early growth stages of *Kockelella stauros* Barrick and Klapper resemble *O. transitans* α morphotype in oral configuration, but they have a posteriorly expanded basal cavity.

Genus *Pandorinellina* Müller and Müller, 1957

Pandorinellina steinhornensis (Ziegler, 1956) subsp. or subspp.

Plate 3, figures 1, 3, 6, 7 and 12

1956 *Spathognathodus steinhornensis* Ziegler, p. 104; Pl. 7, figs. 3-10.

Material: GSC loc. C-87548.

Remarks: Specimens corresponding to a generalized concept of *P. steinhornensis* are common in some faunas from Howards Pass. The stratigraphically oldest specimens (Pl. 3, figs. 1, 3) have slightly thickened platforms over the basal cavity and relatively larger and lower posterior denticles. Most younger specimens are characterized by subequal denticles of generally uniform height and size. One specimen (Pl. 3, fig. 12) has two high denticles at the anterior end and a relatively short process posterior to the symmetrically expanded basal cavity: it resembles *P. optima* Moskalenko. Some specimens resemble *P. steinhornensis* n. subsp. of Lane and others (1979) in denticulation and basal configuration, but do not have the extremely long posterior process. The material at hand does not allow full consideration of speciation within this large group.

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APPENDIX

Biostratigraphic Data, Graptolites

GSC loc. C-87881

62°29.8'N, 129°28.5'W; lower Earn Group

Fauna: *Monograptus yukonensis* Jackson and Lenz
Age: Pragian, *yukonensis* Zone

GSC loc. C-88046

62°18'36"N, 129°27'54"W; lower Earn Group, near contact with underlying Road River Formation (orange-weathering mudstone unit)

Fauna: *Monograptus* cf. *M. thomasi* Jaeger
Age: Pragian, probably *thomasi* Zone

GSC loc. C-60082

62°27.6'N, 129°49.6'W; 32 km west of Howards Pass; orange-weathering mudstone unit of Road River Formation

Fauna: sponge spicules
Bohemograptus bohemicus (Barrande) cf. *B. bohemicus tenuis* (Boucek)
Age: Ludlow, probably *leintwardinensis primus* Zone

GSC loc. C-79641

62°28.3'N, 129°01'W; Road River Formation, shale-chert unit, 1 m below orange-weathering mudstone unit

Fauna: *Cyrtograptus rigidus* Tullberg
Monograptus antennularius Meneghini
M. cf. *M. flemingii* (Salter)
Plectograptus? sp.
Pristiograptus sp.
Age: Wenlock, *rigidus* Zone

GSC loc. C-47982

62°09'N, 128°32'W; Road River Formation, shale-chert unit

Fauna: *Cyrtograptus*? sp.
Monograptus 2 spp.
M. ex gr. *M. spiralis* (Geinitiz)
Retiolites sp.
Age: latest Llandovery, *spiralis* Zone or *sakmaricus-laqueus* Zone

GSC loc. C-83035

62°28'N, 129°10.5'W; X-Y Property; Howards Pass; Road River Formation, shale-chert unit, from 40 cm of beds, about 16 m below orange-weathering mudstone unit

Fauna: *Cyrtograptus* cf. *C. laqueus* Jackson and Etherington
Monograptus? sp.
Pseudoplegmatograptus sp.
Age: latest Llandovery, *sakmaricus-laqueus* Zone

GSC loc. C-83034

Same locality as C-83035; Road River Formation, shale-chert unit, from 40 cm of beds, about 7 m below C-83035 and about 23 m below orange-weathering mudstone unit

Fauna: *Monograptus* ex gr. *M. priodon* (Bronn)
M. ex gr. *M. spiralis* (Geinitz)
Retiolites sp.
Age: Late Llandovery, *spiralis* Zone

GSC loc. C-82889

Same general locality as C-83035; DDH 53, depth 112 ft (34 m); Road River Formation, shale-chert unit

Fauna: graptolite fragments
Monograptus sp.
Age: Silurian, most probably Middle Llandovery or younger

GSC loc. C-107951

Same general locality as C-83035; main adit, 1279-1285 ft (389.8-391.7 m) in from portal, beyond fault zone; probably upper part of "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna: biserial graptolite
Glyptograptus? sp.
Monograptus 2 spp.
M.? sp.
Rastrites sp. or *Monograptus* sp. of *triangulatus* group or of *spiralis* group
Age: Middle, or possibly Late Llandovery

GSC loc. C-104131

Same general locality as C-83035; first crosscut (subsurface), north segment, 293-299 ft (89.3-91.1 m), at least 50 ft (15.2 m) above base of "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna: *Climacograptus*? sp.
Monograptus cf. *M. gregarius arcuatus* (Obut and Sobolevskaya)
Age: Early Llandovery, *acinaces* Zone or *cyphus* Zone, or possibly early Middle Llandovery, *gregarius* Zone.

GSC loc. C-76434

62°23.6'N, 129°06.6'W; 6.5 km west of 7171 ft (2185.7 m) peak; Road River Formation

Fauna: *Climacograptus* sp.
Glyptograptus sp.
Monograptus spp.
M. aff. *M. triangulatus* (Harkness)
Rastrites? sp.
Age: Middle to early Late Llandovery, *gregarius* Zone to *turriculatus* Zone

GSC loc. C-76438

62°25.5'N, 129°21.8'W; 7.2 km west-northwest of 7171 ft (2185.7 m) peak; Road River Formation

Fauna: *Climacograptus* sp.
Glyptograptus sp.
Monograptus spp.
M. aff. *M. triangulatus* (Harkness)
Age: Middle to early Late Llandovery, *gregarius* Zone to *turriculatus* Zone

GSC loc. C-83038

62°18'N, 129°26.5'W; stratigraphic section 7 km southwest of Summit Lake; Road River Formation, shale-chert unit, about 279-281 m above base

Fauna: *Climacograptus* sp.
Glyptograptus sp.
Monograptus spp.
M. buddingtoni Churkin and Carter
M. cf. *M. clingani* (Carruthers)
M. aff. *M. sidjachenkoi* (Obut and Sobolevskaya)
M. cf. *M.*? *triangulatus*? *orbitus* (Churkin and Carter)
Orthograptus? sp.
Petalograptus sp.
P. cf. *P. palmeus* (Barrande)
Rastrites cf. *R. longispinus* Perner
R. pheloides Törnquist
Age: Middle Llandovery, *convolutus* Zone.

GSC loc. C-83037

Same locality as C-83038; Road River Formation, shale-chert unit, talus at about 130 m above base

Fauna: *Atavograptus* aff. *A. gracilis* Hutt
Climacograptus sp.
Glyptograptus sp.
Monograptus sp.
M. gregarius arcuatus (Obut and Sobolevskaya)
M. cyphus Lapworth
Age: Early Llandovery, *cyphus* Zone

GSC loc. C-88040

62°52.6'N, 130°19.4'W; Road River Formation, shale-chert unit

Fauna: inarticulate brachiopods
Climacograptus sp.
Dicellograptus cf. *D. complanatus ornatus* Elles and Wood
Orthograptus cf. *O. truncatus abbreviatus* Elles and Wood
retiolitid graptolite
Age: Ashgill, *complanatus ornatus* Zone

GSC loc. C-83033

62°18.5'N, 128°10'W; near Vulcan Property; Road River Formation, shale-chert unit

Fauna: *Dicellograptus complanatus ornatus* Elles and Wood
Orthograptus sp.
Age: Ashgill, *complanatus ornatus* Zone

GSC loc. C-92580

62°28.5'N, 130°01'W; ridge crest 1 km northwest of 5772 ft (1759.3 m) peak; talus from 10 m outcrop of Road River Formation

Fauna: *Climacograptus hastatus* Hall
Dicellograptus complanatus ornatus Elles and Wood
Orthograptus? sp.
Age: Ashgill, *complanatus ornatus* Zone

GSC loc. C-92576

62°29'N, 130°00.5'W; north end of ridge from 5772 ft (1759.3 m) peak; from 2 m of Road River Formation

Fauna: *Climacograptus* sp.
Dicellograptus sp.
Orthograptus sp.
Reteograptus cf. *R. pulcherrimus* Keble and Harris
Age: Caradoc or Ashgill, probably *quadrimucronatus* Zone

APPENDIX (cont'd)

GSC loc. C-23515

62°27'40"N, 129°14'W; 8.5 miles north-northeast of Summit Lake; Road River Formation, about 100 m above Rabbitkettle Formation

Fauna: inarticulate brachiopod
Climacograptus ex gr. *C. bicornis* (Hall)
Dicranograptus sp.
Orthograptus calcaratus grandis (Ruedemann)
Age: Caradoc, *gracilis-bicornis* Zone to *quadrimucronatus* Zone

GSC loc. 80989

Yukon-Mackenzie Divide at 62°23'52"; north-northwest of Summit Lake; Road River Formation

Fauna: *Climacograptus* ex gr. *C. bicornis* (Hall)
Dicellograptus sp.
Orthograptus sp.
Age: Caradoc or Ashgill

GSC loc. C-76436

62°24'N, 129°18.5'W; 4.5 km west-southwest of 7171 ft (2185.7 m) peak; Road River Formation

Fauna: *Climacograptus* ex gr. *C. bicornis* (Hall)
Dicranograptus sp.
Orthograptus sp.
Pleurograptus? sp.
Age: Caradoc, *gracilis-bicornis* Zone to *quadrimucronatus* Zone

GSC loc. C-76435

62°29.9'N, 129°13.7'W; 9.4 km north of 7171 ft (2185.7 m) peak; Road River Formation

Fauna: fragmentary graptolites
Climacograptus? sp.
Dicranograptus sp.
Leptograptus? sp.
Age: Caradoc, *gracilis-bicornis* Zone to *quadrimucronatus* Zone

GSC loc. C-87897

62°46.5'N, 130°01'W; Road River Formation

Fauna: inarticulate brachiopod
Climacograptus? sp.
Dicellograptus? sp.
Orthograptus cf. *O. truncatus* (Lapworth)
Age: Caradoc, *gracilis-bicornis* Zone to *quadrimucronatus* Zone

GSC loc. C-87798

62°32'12"N, 129°49'18"W; Road River Formation

Fauna: dichograptid? fragments
Tetragraptus sp.
T. approximatus Nicholson
Age: Arenig, *approximatus* Zone or *fruticosus* Zone

APPENDIX (cont'd)

Biostratigraphic Data, Conodonts

Boreholes and outcrops from which conodonts have been isolated are listed below. Localities are described using Morganti's (1979) informal geographic nomenclature (Howards Pass, No Name Peak, Yara Peak, Sugar Mountain). The uncorrected footages (and approximate metric conversions) are given, as are the weights of the samples from which the faunules have been derived, GSC locality numbers, faunal lists and counts (in parentheses) of conodont elements, approximate geographic localities within the XY Property at Howards Pass, geologic units (both current usuage and that of Morganti, 1979) in which the DDH's are collared, and the units from which the samples originated.

DDH 15 (GSC loc. C-87550)

Southwest side of Yara Peak, and collared in the "flaggy mudstone formation" (orange-weathering mudstone unit of Road River Formation)

Depth 121-126 ft (36.9-38.4 m); thought to lie a short distance beneath the orange-weathering mudstone unit

Fauna:	*Ozarkodina* cf. *O. douroensis* Uyeno	Pa(1)
1.96 kg	*Oulodus*? cf. *O.*? *fluegeli* (Walliser)	M(3), Sc(2), Sb(1), Sa(1)
	Walliserodus sp.	(12)
Age:	late Wenlock to early Ludlow	

Unproductive samples: 236-239 ft, 481-483 ft (71.9-72.8 m, 146.6-147.2 m)

DDH 22 (GSC loc. C-87092)

East of Yara Peak, near the eastern edge of the property. Collared in "upper siliceous mudstone" (within shale-chert unit of Road River Formation)

Depth 353 ft (108 m)

Fauna:	*Dapsilodus*? sp. indet.	(1)
0.86 kg		
Age:	Late Ordovician to Silurian	

DDH 29 (GSC loc. C-86423)

East-southeast of Sugar Mountain. Collared in "upper siliceous mudstone" (within shale-chert unit of Road River Formation)

Sample from trench near collar

Fauna:	*Astropentagnathus irregularis* Mostler	Pa(4), Pb(1)
2.2 kg	"*Rhynchognathodus*" n. sp. of Schonlaub 1971	(1)
	"*Falcodus*?" n. sp. of Schonlaub 1971	(1)
	Oulodus? cf. *O.*? *fluegeli* (Walliser)	(12)
	Panderodus sp.	(2)
	Carniodus sp.	(1)
	Distomodus? sp.	(1)
	undifferentiated ramiform elements (including Pl. 2, figs. 4, 17, 20)	(8)
	mazuelloids	
Age:	Llandovery, probably *celloni* Zone, possibly earlier	

DDH 37 (GSC loc. C-102896) Unproductive sample from 365-370 ft (111.2-112.8 m)

DDH 40 (GSC loc. C-86324)

East side of Sugar Mountain; collared in lower Earn Group

Depth 1145-1150 ft (349-350.5 m); sample within 1 m above the "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	Several hundred tiny specimens of the following:	
1.45 kg	*Oulodus*? *fluegeli* (Walliser)	Pa, Pb, M, Sc, Sb, Sa
	O.? cf. *O.*? *kentuckyensis* (Branson and Branson)	
	Ozarkodina? sp.	
	Walliserodus sp.	
	Dapsilodus sp.	
	Panderodus sp.	
Age:	Llandovery, *kentuckyensis* Zone or *celloni* Zone	

Unproductive samples: 917 ft, 960 ft (279.5 m, 292.6 m)

DDH 42 (GSC loc. C-87704)

West of Yara Peak; collared in Earn Group

Depth 334 ft (102 m); basal Earn Group, immediately above orange-weathering mudstone unit of Road River Formation

Fauna:	*Ozarkodina* cf. *O. excavata excavata* (Branson and Mehl)	(1)
2.40 kg	ramiform fragment	(1)
Age:	Silurian to early Devonian	

Unproductive samples: 917 ft, 960 ft (279.5 m, 292.6 m)

DDH 45 (GSC loc. C-87093)

Northwest side of Yara Peak; collared in "flaggy mudstone formation" (orange-weathering mudstone unit of Road River Formation)

Depth 1019 ft (310.6 m); within orange-weathering mudstone unit

Fauna:	*Dapsilodus*? sp.	(1)
1.5 kg	ramiform fragment	(2)
Age:	Late Ordovician-Silurian	

Depth 1190 ft (362.7 m); near top of "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	*Oulodus*? cf. *O.*? *fluegeli* (Walliser)	Sa(1), Sc(1)
0.77 kg	*Dapsilodus* sp.	(1)
Age:	Early to Middle Silurian	

Depth 1225 ft (373.4 m); near base of "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	silicified fragments, indet.
0.78 kg	

Unproductive samples: 645 ft, 763 ft, 1225 ft (196.6 m, 232.6 m, 373.4 m)

DDH 68 (GSC loc. C-102897) Unproductive samples from 357 ft, 457 ft

DDH 80 (GSC loc. C-87094)

South side of Sugar Mountain; collared in lower Earn Group

Depth 122 ft (37.2 m); within lower Earn Group

Fauna:	ramiform elements (including Pl. 3, fig. 15)	(25)
0.85 kg		
Age:	not diagnostic	

Depth 250 ft (76.2 m); basal Earn Group; about 8 m above Road River Formation

Fauna:	*Ancoradella ploeckensis* Walliser	(1)
0.97 kg	undifferentiated ramiform elements	(8)
	mazuelloids	(3)
Age:	Ludlow, *ploeckensis* Zone or *siluricus* Zone	

Depth 527 ft (160.6 m), within orange-weathering mudstone unit of Road River Formation

Fauna:	*Walliserodus*? sp.	(1)
0.69 kg	ozarkodiniform element (Pl. 3, fig. 9)	(1)
	ramiform fragment	(1)
Age:	Silurian	

Depth 811 ft (247.2 m); "upper siliceous mudstone" (within shale-chert unit of Road River Formation)

Fauna:	*Panderodus* sp.	(7)
1.17 kg	*Walliserodus* sp.	(2)
	mazuelloids	(1)
Age:	Silurian	

Depth 875 ft (266.7 m); sample from "upper siliceous mudstone" (within shale-chert unit of Road River Formation)

Fauna:	*Astropentagnathus* cf. *A. irregularis* Mostler	Pa(2)
0.48 kg	ramiform elements	
Age:	Llandovery, probably *celloni* Zone, possibly earlier	

Depth 984 ft (300 m); sample at base of "upper siliceous mudstone", immediately above "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	*Walliserodus* sp.	(6)
1.48 kg	ramiform fragment	(1)
Age:	Llandovery	

Depth 1080 ft (329.2 m); sample from about middle of "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	*Oulodus*? *fluegeli* (Walliser)	Pb(2), M(1), Sc(4), Sb(1), Sa(1),?(3)
0.69 kg	*O.*? cf. *O. kentuckyensis* Branson and Branson	
	Dapsilodus sp.	(3)
	ozarkodiniform element	(1)
Age:	Llandovery, *kentuckyensis* Zone	

Depth 1118 ft (341 m); in lower part of "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	*Oulodus*? cf. *O.*? *fluegeli* (Walliser)	Pa?(1)
0.82 kg	*O.*? cf. *O.*? *kentuckyensis* (Branson and Branson)	Pa?(1), Sa?(1)
	Distomodus? sp.	M(1)
Age:	Llandovery, ?*kentuckyensis* Zone	

Unproductive samples: 37 ft, 91 ft, 250 ft, 1138 ft (11.3 m, 27.7 m, 76.2 m, 346.9 m)

DDH 83 (GSC loc. C-87705)

South of Sugar Mountain; collared in Earn Group

Depth 84 ft (25.6 m); lower Earn Group, 80 m above Road River Formation

Fauna:	ramiform elements	(2)
1.59 kg	mazuelloids	abundant
Age:	not diagnostic	

Unproductive sample: 251 ft (76.5 m)

Depth 300 ft (91.4 m); lower Earn Group, 15 m above Road River Formation

Fauna:	*?Ozarkodina excavata excavata* (Branson and Mehl)	(1)
1.82 kg	*Oulodus* sp.	(1)
	ramiform elements, undifferentiated	(14)
	mazuelloids	(2)
Age:	Silurian	

Depth 846 ft (258 m); phosphatic chert of "upper siliceous mudstone", shale-chert unit of Road River Formation, 19 m below base of orange-weathering mudstone unit of Road River Formation

Fauna:	conodont fragment indet.	(1)
	mazuelloid	(1)

DDH 95 (GSC loc. C-102863)

South side of No Name Peak; collared in lower Earn Group

Depth 114 ft (34.7 m); lower Earn Group

Fauna:	*Ozarkodina* cf. *O. eberleini* Savage	Pa(3)
1.54 kg	*Ozarkodina* sp.	(6)
	Icriodus sp.	(4)
	Pedavis? sp.	(1)
	Belodella? sp.	(1)
	Pseudooneotodus sp.	(3)
	ramiform fragments	
Age:	Early Devonian, possibly *sulcatus* Zone	

Depth 272 ft (83 m)

Fauna:	ramiform fragment	(1)
1.1 kg		

Depth 476 ft (145 m)

Fauna:	ramiform fragment	(1)
1.1 kg		

Depth 783 ft (238.7 m); near top of orange-weathering mudstone unit of Road River Formation

Fauna:	*Ozarkodina excavata excavata* (Branson and Mehl)	(2)
1.66 kg	ramiform elements	(2)
Age:	Silurian to early Devonian	

DDH 98 (GSC loc. C-86424)

East side of Sugar Mountain; collared in lower Earn Group. Sample near collar

Fauna:	*Icriodus steinachensis* Al-Rawi *sensu lato*	Pa(9), M(4)
3.0 kg	*Oulodus*? *walliseri* (Ziegler)	(1)
	Ozarkodina aff. *O. selfi* Lane and Ormiston	Pa(4)
	Pandorinellina steinhornensis (Ziegler)	Pa(5)
	Belodella sp.	(1)
	Panderodus sp.	(3)
	ramiform elements	(6)
	sponge spicules	abundant
Age:	Lochkovian, probably *pesavis* Zone	

DDH 99 (GSC loc. C-87548)

East side of Sugar Mountain; collared in lower Earn Group

Depth 339 ft (103.3 m); lower Earn Group

Fauna:	*Icriodus steinachensis* Al-Rawi *sensu lato*	Pa(2)
1.45 kg	*Pandorinellina steinhornensis* (Ziegler)	Pa(50)
	undifferentiated ramiform elements	
	sponge spicules	abundant
Age:	Lochkovian, probably *pesavis* Zone	

Depth 404 ft (123 m); lower Earn Group

Fauna:	*Icriodus steinachensis* Al-Rawi *sensu lato*	Pa(7), M&S(10)
1.65 km	*Pseudooneotodus* sp.	(2)
	Pandorinellina steinhornensis (Ziegler)	(27)
	Belodella sp.	(11)
	undifferentiated ramiform elements	
	sponge spicules	abundant
Age:	Lochkovian, probably *pesavis* Zone	

Depth 498 ft (151.8 m); lower Earn Group

Fauna:	*Pandorinellina* sp.	(1)
1.46 kg	ramiform elements	(8)

Depth 648 ft (197.5 m); lower Earn Group

Fauna:	*Ozarkodina transitans*	Pa(1)
1.34 kg	(Bischoff and Sannemann) α morphotype	
	Pandorinellina? *steinhornensis* (Ziegler) group	(4)
	Belodella sp.	(1)
	undifferentiated ramiform elements(16)	
Age:	Lochkovian, *delta* Zone	

Depth 737 ft (224.6 m); lower Earn Group

Fauna:	*Ozarkodina*? sp.	(1)
1.49 kg		
Age:	not diagnostic	

Depth 1390 ft (423.7 m); "upper siliceous mudstone" (within shale-chert unit of Road River Formation)

Fauna:	*Astropentagnathus* aff. *A. transitans*	Pa(1)
1.21 kg	(Schönlaub)	
	Oulodus? *fluegeli* (Walliser)	Pa(1), Sa(1)
	Carniodus sp.	(2)
	Belodella sp.	(2)
	Panderodus sp.	(3)
	mazuelloids	
Age:	Llandovery, *celloni* Zone	

Depth 1438 ft (438.3 m); just above "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	*Oulodus*? *fluegeli* (Walliser)	Pa?, Pb, M, Sc, Sa(7)
0.89 kg	*O.*? cf. *O.*? *kentuckyensis*	
	(Branson and Branson)	
	Distomodus sp.	Sa(1)
	Dapsilodus sp.	(2)
	sponge spicules	
Age:	Llandovery, *kentuckyensis* Zone or *celloni* Zone	

Depth 1490 ft (454 m); sample from "Active Zone Member" (within shale-chert unit of Road River Formation)

Fauna:	indeterminate organic fragments
1.03 kg	

Unproductive samples: 915 ft, 1522 ft (278.9 m, 463.9 m)

APPENDIX (cont'd)

GSC loc. C-86285

62°25.8'N, 129°18'W; 4 km west-northwest of 7171 ft (2185.7 m) peak; lower Earn Group

Fauna:	*Palmatolepis glabra* Ulrich and Bassler	Pa(9)
	Polygnathus sp.	(2)
	undifferentiated ramiform elements	
Age:	early to middle Famennian	

GSC loc. C-86286

62°27.6'N, 129°19.0'W; 7.0 km northwest of 7171 ft (2185.7 m) peak; lower Earn Group

Fauna:	*Palmatolepis glabra* Ulrich and Bassler group	Pa(1)
	Polygnathus sp.	Pa(2)
	"*Spathognathodus*?" sp.	Pa(1)
	undifferentiated ramiform elements	
Age:	early to middle Famennian	

GSC loc. C-86287

62°28.0'N, 129°10.5'W; 6.5 km north-northeast of 7171 ft (2185.7 m) peak; lower Earn Group

Fauna:	*Polygnathus pireneae* Boersma	Pa(1)
	Pandorinellina steinhornensis (Ziegler)	Pa(9)
	undifferentiated ramiform elements	(3)
Age:	Pragian, *kindlei* Zone or *dehiscens* Zone	

GSC loc. C-86288

62°29.5'N, 129°13.6'W; 9 km north of 7171 ft (2185.7 m) peak; lower Earn Group

Fauna:	*Polygnathus* cf. *P. dehiscens* Philip and Jackson	Pa(3)
	P. gronbergi Klapper and Johnson	Pa(2)
	Pandorinella cf. *P. steinhornensis* (Ziegler)	Pa(2)
	Belodella sp.	(1)
	undifferentiated ramiform elements	
	hexactinellid sponge spicules	
Age:	Zlichovian *gronbergi* Zone	

GSC loc. C-86413

62°25.7'N, 129°15.8'W; lower Earn Group

Fauna:	*Palmatolepis* cf. *P. triangularis* Sannemann	Pa(1)
3.23 kg	*P.* cf. *P. delicatula* Branson and Mehl	Pa(1)
	P. sp.	Pa(2)
	Polygnathus sp.	Pa(2)
	undifferentiated ramiform elements	
Age:	late Frasnian-early Famennian	

GSC loc. C-87045

62°17'22"N, 128°54'15"N; Unit 76 of Map 8-1967

Fauna:	*Amorphognathus* or *Eoplacognathus* fragments	(50+)
1.64 kg	*Periodon aculeatus* (Hadding)	(46)
	Drepanoistodus cf. *D. suberectus* (Branson and Mehl)	(16)
	D.? *venustus*? (Stauffer)	(3)
	Belodina sp.	(1)
	Protopanderodus sp.	(8)
	Panderodus? sp.	(2)
	Walliserodus? sp.	(2)
	Scabbardella? sp.	(12)
Age:	probably Middle Ordovician	

GSC loc. C-87552

62°27'7"N, 129°26'0"W; lower Earn Group

Fauna:	?*Tortuodus kockelianus* (Bischoff and Ziegler)	Pa(1)
1.9 kg		
Age:	middle or late Eifelian	

GSC loc. C-87553

62°28'N, 129°17'W; lower Earn Group

Fauna:	*Icriodus taimyricus* Kuzmin	(1)
1.89 kg	*Polygnathus* aff. *P. dehiscens* Philip and Jackson	Pa(85)
	Pandorinellina? sp.	(4)
	Panderodus sp.	(3)
	ramiform elements	(44)
Age:	Pragian, Zlichovian, *dehiscens* Zone	

PLATES 1-4

Conodonts and graptolites from the
Road River Formation and Earn Group

PLATE 1

Oulodus? cf. *O.*? *kentuckyensis* (Branson and Branson) (page 11)

Figures 1, 6. Postero-lateral and lower views of oulodiform elements, GSC 65981; DDH 80.1118; GSC 65982, DDH 40.1145-50, x100.

3, 7, 8, 11. Posterior and anterior (fig. 11) views of trichonodelliform (Sa) elements, GSC 65993, DDH 99.1438, x80; GSC 65994, DDH 80.1080, x80; GSC 65995, DDH 40.1145-50, x120; GSC 65996, DDH 40.1145-50, x100.

Oulodus? *fluegeli* (Walliser) (page 11)

2, 9, 10, 12-14, 16-18, 20, 21. All from DDH 40.1145-50 except figure 2. Posterior (figs. 2, 13) and anterior (fig. 9) views of trichonodelliform (Sa) elements, GSC 65983, DDH 80.1080, x100; GSC 65984, x100; GSC 65985, x120. Posterior view (fig. 10) of 'zygognathiform' (Sb) element, GSC 65986, x120. Lateral view (fig. 12) of 'cyrtoniodiniform' (M) element, GSC 65987, x100. Upper and lateral views (figs. 14, 16) of modified spathognathodiform (Pa) element, GSC 65988, x150. Outer lateral (figs. 17, 20), and inner postero-lateral (fig. 21) views of modified oulodiform (Pb) elements, GSC 65989, x150; GSC 65990, x150; GSC 65991, x100. Lateral view (fig. 18) of hindeodelliform (Sc) element, GSC 65992, x120.

Distomodus? sp. (page 11)

Figure 4. Posterior view of exochognathiform (Sa) element, GSC 65997, DDH 99.1438, x80.

Dapsilodus sp. (not described)

5. Lateral view of distacodiform element, GSC 65998, DDH 80.1080, x80.

Genus and species undetermined 1 (not described)

15. Lateral view of ozarkodiniform element, GSC 65999, DDH 80.1080, x80.

Ozarkodina excavata excavata (Branson and Mehl) (not described)

19. Lateral view of spathognathodiform element, GSC 66000, DDH 95.783, x60.

Mazuelloids (not described)

Figures 22-24. All from DDH 29, sample near collar. Figure 22 (GSC 66001, x250), note pores beginning on inner wall of broken part extending through robust tapering spines on outer wall. Figure 23 (GSC 66002, x200), an incompletely(?) preserved specimen shows bases of thin, rod-like spines, one of which adheres to left centre. Figure 24 (GSC 66003, x200), a specimen, reveals broken outer spine with thin inner spine protruding lower left.

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PLATE 2

Specimens from DDH 29 (sample near collar) unless stated otherwise.

Ancoradella ploeckensis Walliser (page 10)

Figure 1. Upper view of Pa element, GSC 66004, DDH 80.250, x30.

Astropentagnathus irregularis Mostler (page 10)

Figures 2, 3, 6. Upper and lower views of astropentagnathiform (Pa) elements, GSC 66005, x60; GSC 66006, x60; oral view of neospathognathodiform (Pb) element, GSC 66007, x60.

Genus and species undetermined 2 (not described)

Figure 4. Posterior view of diplodelliform element, GSC 66008, x75.

Astropentagnathus aff. *A. transitans* (Schönlaub) (page 10)

5. Upper view of astropentagnathiform (Pa) element, GSC 66009, DDH 99.1390, x80.

Distomodus? sp. (page 11)

7. Posterior view of exognathiform (Sa) element, GSC 66010, x75.

Oulodus? cf. *O.*? *fluegeli* (Walliser) (page 11)

Figures 8, 9, 12, 15, 16, 23, 24. Posterior view of 'zygognathiform' (Sb) element, GSC 66011, x75. Lateral views of hindeodelliform (Sc) elements, GSC 66012, x75; GSC 66013, x35. Outer lateral and inner lateral views of modified oulodiform elements, GSC 66014, x60; GSC 66015, x75; GSC 66016, x75. Lateral view of 'cyrtoniodiniform' (M) element GSC 66017, x75. No Pa element recovered.

"Rhyncognathodus" (n. sp. *sensu* Schönlaub) (not described)

Figure 10. Posterior view, GSC 66017, x75.

Falcodus? (n. sp. *sensu* Schönlaub) (not described)

11. Posterior view, GSC 66018, x75.

Ozarkodina cf. *O. duoroensis* Uyeno (*sensu* Uyeno 1981) (page 11)

Figures 13, 14. Lateral and upper views of bispathodiform (Pa) element, GSC 66019, DDH 15.121-126, x45.

Genus and species undetermined 3 (not described)

17, 20. Lateral views of two hindeodelliform elements, GSC 66020, 66021, x75.

Panderodus sp. (not described)

Figure 18. Lateral view of unicostate element, GSC 66022, x75.

Carniodus sp. (not described)

Figures 19, 22. Elements, GSC 66023, x100; GSC 66024, DDH 99.1390, x80.

Walliserodus sp. (not described)

Figure 21. Lateral view of multicostate element, GSC 66025, DDH 80.984, x80.

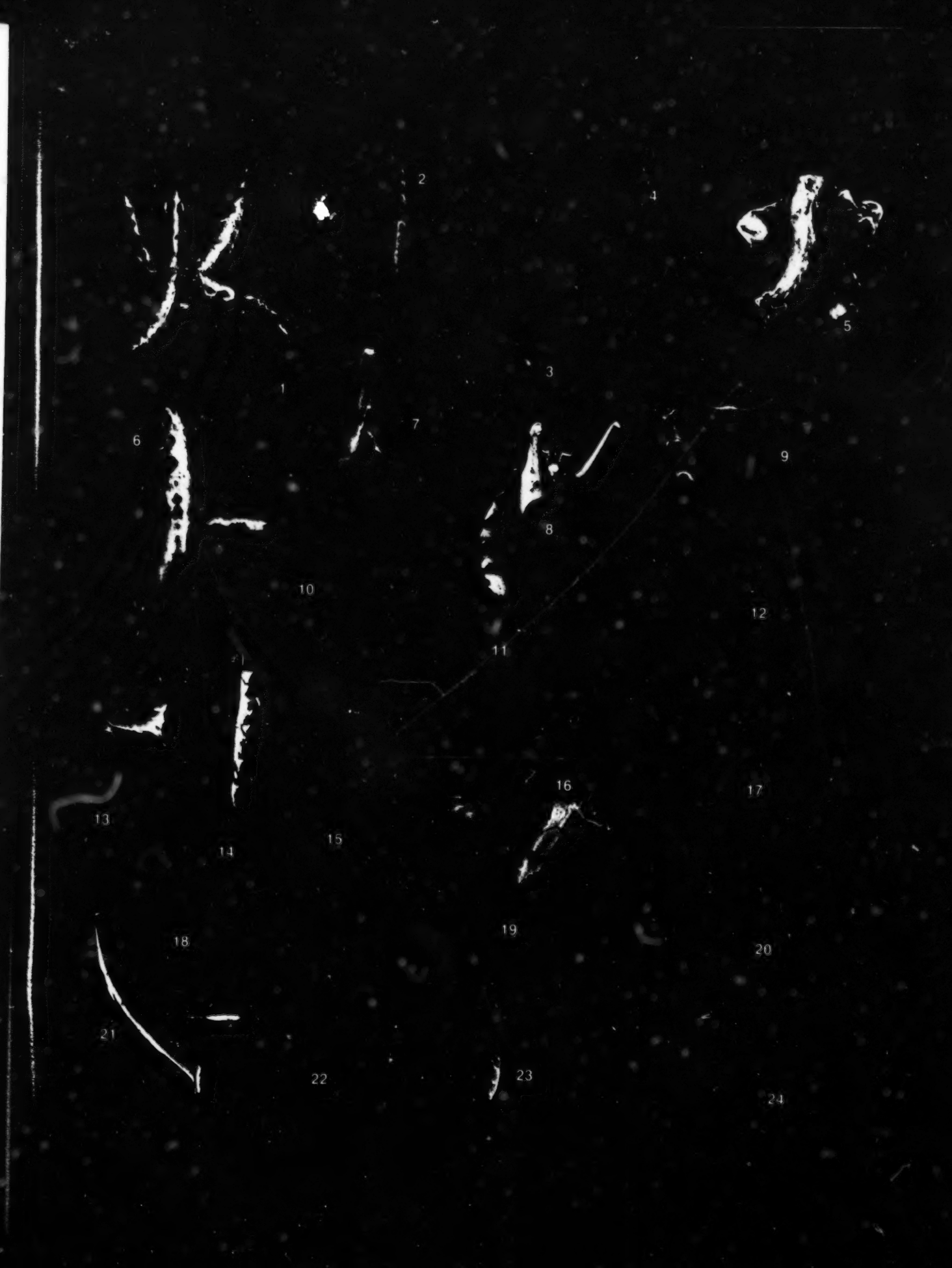
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PLATE 3

Pandorinellina steinhornensis (Ziegler) subspecies (page 12)

Figures 1, 3, 6, 7, 12. Upper and lateral views of spathognathodiform (Pa) elements, GSC 66026, 66027, DHH 99.6404, x80; GSC 66032, 66033, 66037, DDH 99.339, x60.

Ozarkodina transitans (Bischoff and Sannemann) α morphotype of Lane and Ormiston (page 12)

Figure 2. Upper view of spathognathodiform (Pa) element, GSC 66028, DDH 99.648, x80.

Icriodus steinachensis Al-Rawi *sensu lato* (page 11)

Figures 4, 5, 7?11. Upper and lateral views of icriodontiform and drepanodiform (fig. 11) elements, GSC 66029, 66030, 66031, DDH 99.404, x60.

Belodella sp. (not described)

Figure 8. Lateral view of denticulate asymmetric element, GSC 66034, DDH 99.404, x80.

Genus and species undetermined 4 (not described)

9. Lateral view of ozarkodiniform (Pb) element, GSC 66035, DDH 80.528, x75.

Pseudooneotodus sp. (not described)

10. Upper view of element, GSC 66036, DDH 99.404, x75.

Icriodus steinachensis Al-Rawi eta morphotype of Klapper (page 11)

Figures 13, 17, 18. Upper views of icriodontiform elements, GSC 66038, (early growth stage), GSC 66039, 66040, DDH 99.339 and DDH 98, Fig. 17, x50.

Figure 24. Postero-lateral view of costate cone with rudimentary basal denticulation, GSC 66041, DDH 98, x100; material tentatively assigned to the taxon.

Ozarkodina cf. *O. eberleini* Savage (page 12)

14. Lateral view of spathognathodiform (Pa) element, GSC 66042, DDH 95.114, x60.

Genus and species undetermined 5 (not described)

15. Lateral view of ozarkodiniform (Pb) element, GSC 66043, DDH 80.122, x80.

Ozarkodina aff. *O. selfi* Lane and Ormiston (page 12)

16. Upper view of spathognathodiform (Pa) element, GSC 66044, DDH 98, x60.

Polygnathus gronbergi Klapper and Johnson (not described)

19. Upper view of polygnathiform (Pa) element, GSC 66045, GSC loc. C-86288, x75.

Polygnathus cf. *P. dehiscens* Philip and Jackson (not described)

Figures 20, 21. Upper and lower views of polygnathiform (Pa) elements, GSC 66046, 66047, GSC loc. C-86288, x75. Specimens transitional to *P. gronbergi*.

Polygnathus pireneae Boersma (not described)

Figure 22. Upper view of polygnathiform (Pa) element, GSC 66048, GSC loc. C-86287, x75.

Palmatolepis glabra Ulrich and Bassler (not described)

23. Upper view of palmatolepiform (Pa) element, GSC 66049, GSC loc. C-86285 x100. Element is small growth stage and subspecifically indistinct.

Oulodus? *walliseri* (Ziegler) (page 11)

25. Lateral view of walliseriform (Sb) element, GSC 66050, DDH 98, x40.

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PLATE 4

SAKMARICUS-LAQUEUS ZONE

Cyrtograptus cf. *C. laqueus* Jackson and Etherington (page 8)

Figures 1, 3. Views of rhabdosomes GSC 63578, 63579, both partly obscured by fragments and less complete rhabdosomes of the same taxon, GSC loc. C-83035, x2. Fragments of *Pseudoplegmatograptus* sp. also present in figure 3, of *Monograptus*? sp. in figure 1.

Pseudoplegmatograptus sp. (not described)

Figure 2. Rhabdosome fragment, GSC 63580, GSC loc. C-83035, x2. Other fragments shown by figure 3.

SPIRALIS ZONE

Monograptus ex gr. *M. spiralis* (Geinitz) (page 9)

Figure 4. Most complete rhabdosome, GSC 63581, GSC loc. C-83034, x2.

Retiolites sp. (page 10)

5. Large rhabdosome, GSC 63582, GSC loc. C-83034, x2. Proximal part somewhat distorted.

CONVOLUTUS ZONE

Petalograptus cf. *P. palmeus* (Barrande) (page 9)

Figure 6. Rhabdosome, GSC 63583, GSC loc. C-83038, x2.

Monograptus triangulatus cf. *M.? triangulatus? orbitus* (Churkin and Carter) (page 9)

7. Most complete rhabdosome, GSC 63584, proximal part poorly preserved; GSC loc. C-83038, x5.

Monograptus aff. *M. sidjachenkoi* (Obut and Sobolevskaya) (page 9)

8. Rhabdosome, GSC 63585, GSC loc. C-83038, x5.

Monograptus buddingtoni Churkin and Carter (page 8)

9. Rhabdosome, GSC 63586, GSC loc. C-83038, x5.

Monograptus cf. *M. clingani* (Carruthers) (page 8)

10. Incomplete rhabdosome, GSC 63587, together with a small fragment and also a fragment of an undetermined and undescribed species of *Monograptus*, GSC loc. C-83038, x2.

Rastrites cf. *R. longispinus* Perner (page 10)

11. Small fragment, GSC 63588, GSC loc. C-83038, x5.

Rastrites pheloides Törnquist (page 10)

12. Small fragment, GSC 63589, GSC loc. C-83038, x5.

Petalograptus sp. (page 9)

13. Rhabdosome, GSC 63590, GSC loc. C-83038, x5.

CYPHUS ZONE

Monograptus sp. (not described)

Figure 14. Rhabdosome fragment, GSC 63591, GSC loc. C-83037, x2.

Atavograptus aff. *A. gracilis* Hutt (page 8)

15. Rhabdosome fragment, GSC 63592, GSC loc. C-83037, x5.

Monograptus gregarius arcuatus (Obut and Sobolevskaya) (page 8)

Figures 16-18. Three rhabdosomes, GSC 63593-63595, GSC loc. C-83037, x5. Apertural spine of sicula well shown in figure 18. Figure 17 shows associated undetermined and undescribed species of *Climacograptus* and *Glyptograptus*.

Monograptus cyphus Lapworth (page 8)

Figure 19. Rhabdosome, GSC 63596, GSC loc. C-83037, x2.

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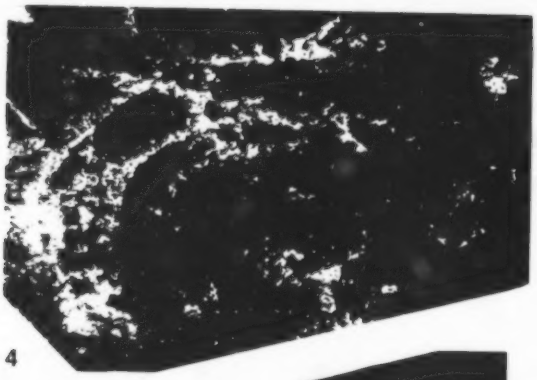
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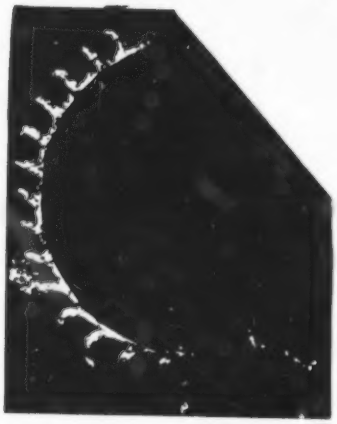
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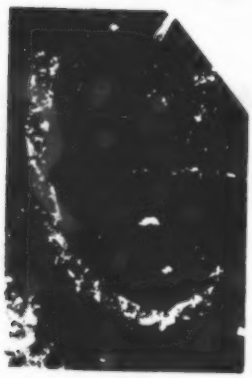
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